

## Operation CROSSROADS

**Note:** For information related to claims, call the Department of Veterans Affairs (VA) at 800-827-1000 or the Department of Justice (DOJ) at 800-729-7327. For all other information, call the Nuclear Test Personnel Review (NTPR) Program at 800-462-3683.

Operation CROSSROADS, conducted in July and August 1946, was the first nuclear test series after World War II and the first ever in the ocean. It consisted of two nuclear tests – one airburst and one underwater – using nuclear devices very similar to the one dropped on Nagasaki, Japan, in August 1945. The tests were conducted against an array of more than 90 target ships in the lagoon of Bikini Atoll, part of the Marshall Islands in the Pacific. They were intended to study the effects of nuclear weapons on naval ships, equipment, and materiel. Unlike almost all U.S. atmospheric tests that followed, CROSSROADS included no weapon development experiments. CROSSROADS was the largest nuclear test operation and at the time the largest U.S. peacetime military operation ever conducted, involving 45,400 men, 220 ships, and 160 aircraft.

When the atomic bomb attacks on Japan abruptly ended World War II, many leaders believed that military science was at a crossroads. Vice Admiral W.H.P. Blandy, Commander of Operation CROSSROADS, commented that “warfare, perhaps civilization itself, has been brought to a turning point by this revolutionary weapon” and thus gave the operation its name.

Only weeks after the Hiroshima and Nagasaki attacks, some leaders in the U.S. Government began proposing that the awesome power of this new atomic weapon be demonstrated to the world by inviting the international press to witness the dropping of one on an array of captured Japanese ships. The Navy, however, requested that the demonstration be broadened into a scientific test by including modern, fully equipped U.S. ships in the array and staging experiments designed to produce useful information not available from the TRINITY test or the Hiroshima and Nagasaki bombings. President Truman subsequently approved the detonation of three nuclear weapons – one-third of the U.S. stockpile at the time.

In January 1946, the Joint Chiefs of Staff created an organization to conduct the tests: Joint Task Force 1 (JTF), formed from elements of the Navy, the Army, the Army Air Force, and civilian scientists from the Manhattan Engineer District. This organization was modeled after joint task forces established during World War II for amphibious assaults, although with the added element of civilian scientists. A total of about 44,000 members of the armed services are on record as being participants of CROSSROADS, and about 90 percent of these were Navy personnel.

Although the original purpose of the operation was to help the Navy improve the design of ships and naval tactics, the Army requested that experiments be added to study the effects of a nuclear detonation on Army equipment and installations. And the Army Air Force was eager for the opportunity to train its pilots in attack techniques using atomic bombs against ships. As planning progressed, more experiments were added to gather data on the nature, range, and duration of radiation intensities, to measure the blast, heat, radiation, and electromagnetic phenomenology from a nuclear detonation, and to develop techniques for long-range detection.

## Shot Summary<sup>a</sup>

Shot	Local Date (1946)	Location	Burst Type	Yield <sup>b</sup>
ABLE	July 1	Bikini Lagoon	Airdrop (520 feet)	21 kilotons
BAKER	July 25	Bikini Lagoon	Underwater (-90 feet)	21 kilotons

<sup>a</sup>Source: “*United States Nuclear Tests, July 1945 through September 1992*”, DOE/NV-209 (Rev. 15), Dec 2000.

<sup>b</sup>One kiloton equals the approximate energy release of one thousand tons of TNT.

Shot CHARLIE, a deep underwater detonation, was planned but never conducted. It was cancelled a few weeks after BAKER.

## Preparations and Experiments

Before CROSSROADS could begin, a site had to be found that offered these features: a protected anchorage; a location at least 300 miles from any city; no or very few inhabitants; a warm climate, free from violent storms; predictable winds; predictable water currents away from fishing areas, ocean shipping lanes, and inhabited shores; and control by the United States. After considering several sites around the world, the JTF chose Bikini Atoll at the northern extreme of the Marshall Islands.

Preparations in the Pacific began during spring 1946. In March, the 167 native Bikinians were permanently evacuated to neighboring Rongerik Atoll, 130 nautical miles (nmi) to the east, where the Navy built 26 house frames and infrastructure to help the evacuees adjust to their new home. The only structures built on Bikini were light recreation facilities, instrumentation towers, and a temporary construction camp. The support fleet of about 130 ships provided quarters, experimental stations, and workshops for most of the JTF. Additional JTF personnel were located on nearby atolls, such as Enewetak (190 nmi to the west) and Kwajalein (210 nmi to the southeast).

The focus of the operation was the unmanned fleet of more than 90 vessels anchored in Bikini Lagoon that served as the target array for both shots. These target ships included older U.S. capital ships – among them the famous aircraft carrier USS SARATOGA (CV 3) and battleships USS NEVADA (BB 36), USS PENNSYLVANIA (BB 38), and USS NEW YORK (BB 34) – three captured German and Japanese ships; surplus U.S. cruisers, destroyers, and submarines; and a number of auxiliary and amphibious vessels. At the center of the array, closest to the intended surface zero, were expendable ships not expected to be usable after the operation. Some were expected to sink with the ABLE test and more with the BAKER underwater test. Ships on the perimeter of the array were active, commissioned vessels that were expected to suffer only minor damage, be reboarded, repaired, and remanned. Amphibious craft were beached on the lagoon side of Bikini Island to assess their ability to withstand waves created by the blast. Much of the CROSSROADS experimental program consisted simply of exposing a wide range of equipment and materiel to the effects of the nuclear detonation and documenting the results.

How well each ship's hull, superstructure, machinery, and electrical system would stand up to the blast and heat was a key question; consequently, some of the "war-weary" target ships had to be reconditioned at stateside Naval shipyards to return them to minimum standards. To simulate normal fighting condition, the target ships were provisioned with live ammunition, torpedoes, radar equipment, and standard amounts of fuel, food, and supplies. In addition, Army trucks, tanks, ammunition, gun mounts, radar and electrical equipment, aircraft parts, chemicals, fire-fighting equipment, lubricants, fuels, field stoves, and clothing were carefully arrayed on the decks of the target ships, documented, and photographed. The conditions of all compartments and systems of every ship were also examined and photographed. In addition, the medical group placed pigs, goats, guinea pigs, rats, mice, bacteria, seeds, and medical supplies on upper and lower decks.

More than 10,000 measuring devices (including 200 cameras) for collecting data on the effects of the detonation were positioned on the islands, the support fleet, and aircraft, with the majority being placed on the target fleet. The effect of the detonation on in-flight aircraft was measured by positioning specially instrumented planes at various distances from the blast. Those within the danger zone were remote-controlled drone aircraft.

After each shot, drone aircraft flew through the nuclear cloud to collect samples. Drone boats, which were the first craft to enter the lagoon, collected water samples and surveyed the radiation intensities before radiation monitors could be permitted to enter the area. As radiation levels allowed, specially trained boarding parties and then regular crews followed to reboard the ships, assess the damage, take photographs, and begin to collect data and prepare the ships for BAKER by replacing experiments and instruments. After BAKER, they planned to send equipment and samples to the continental United States for analysis, reboard and activate all salvageable ships, and scuttle those beyond repair.

### **Shot ABLE**

Immediately before Shot ABLE, the ships of the support fleet evacuated all personnel from the target fleet and from Bikini Atoll to safe positions at least 10 nmi east and upwind of the atoll. At shot time, about 80 JTF aircraft were airborne. VIP observers on the support ships included U.S. Congressmen, representatives of the President and the Joint Chiefs of Staff, United Nations representatives, and a large contingent from the international press.

A B-29 named "Dave's Dream" released the weapon at 8:59 a.m. on July 1. The device detonated above Bikini Lagoon at an altitude of 520 feet, but it was off-target by 1500 to 2000 feet to the west of the planned surface zero, marked by USS NEVADA (BB 36). Five ships were sunk, six seriously damaged, 17 somewhat damaged, and 43 suffered "negligible damage." The amphibious craft beached on Bikini Island were unscathed. In general, vessels within 500 yards of surface zero were sunk or seriously damaged; those beyond 1500 yards received only minor damage.

The radioactivity created by the burst was low enough that within a day, nearly all surviving target ships had been safely reboarded. The ship inspections, instrument recoveries, and remooring necessary for Shot BAKER proceeded on schedule, and ships beyond 750 yards were safe enough to be used for crew quarters within two days. By July 5, all target vessels still afloat had been rehabilitated enough to be prepared for BAKER.

## **Shot BAKER and its Aftermath**

Shot BAKER was expected to cause more damage to the target fleet than ABLE because it was an underwater detonation and closer to the surface. It was also expected to produce more radioactive contamination in Bikini Lagoon – although no one knew how much more. As it turned out, contamination from BAKER caused major problems that persisted for months and threatened the overall success of the operation.

Pre-shot procedures were essentially the same as for ABLE: 68 target ships were moored in the lagoon and 24 small craft were beached on Bikini; all personnel were evacuated to the support fleet, which retreated upwind; and VIP observers and the press awaited the shot.

The BAKER device was suspended in a waterproof caisson 90 feet below one of the smaller vessels in the center of the target fleet. It was detonated on schedule at 8:35 a.m. on July 25. According to an eyewitness report, a “white chimney of water” rose up several thousand feet “its head enshrouded in a tumult of steam. Then slowly the pillar began to fall and break up. At its base a tidal wave of spray and steam rose to smother the fleet...” Another observer reported seeing a major ship “on its nose” before it sank (an optical illusion).

BAKER inflicted heavy damage on the target fleet. Eight ships, including SARATOGA, were sunk; eight more were seriously damaged. Even more important for the remainder of the operation, the detonation caused most of the target fleet to be bathed in radioactive water spray containing debris from the nuclear device, mixed with material dredged from the lagoon bottom.

The water in the lagoon near surface zero was intensely radioactive for several days. By July 30, many target ships remained too radioactive for boarding, and it was becoming apparent that the target fleet was much more heavily contaminated than had been expected. For all but 12 target vessels, the target fleet remained too radiologically contaminated to allow more than brief onboard activities. Most of the thorough inspection and documentation of BAKER’s effects, a primary objective of Operation CROSSROADS, was seriously delayed.

Within a week after the detonation, JTF commanders realized that they had to attempt to decontaminate the target vessels, even though they acknowledged that “since the nature and extent of contamination of the targets was completely unexpected, no plans had been prepared for organized decontamination measures.” Beginning on August 1, work crews drawn from the target ships companies sprayed and scrubbed the ships exteriors – always under the supervision of radiation safety (rad-safe) monitors equipped with radiac instruments. Initially, decontamination proceeded slowly because safe time aboard some of the target ships was severely limited, sometimes to only a few minutes. Also, removing the radioactive particles imbedded in the paint, rust, and organic materials of the ships was a very slow and labor-intensive process. Crews experimented with a variety of techniques and decontaminating agents – including blasting with ground coconut shells, rice, ground coffee, and sand – but none worked well enough to significantly speed up the process.

In the meantime, radioactive contaminants in the water had spread to the lagoon anchorage of the support fleet. This became a serious problem as contamination accumulated in the ships’ evaporators, saltwater piping, and marine growth on the outside of their hulls, potentially exposing shipboard personnel to low-level radiation.

By August 10, the increasing contamination of the support fleet, the futile decontamination effort of the target fleet, and finally the persistence of alpha radiation emitters (e.g., plutonium) on the ships forced the JTF to order an end to the decontamination work in Bikini and the towing of salvageable ships to Kwajalein Atoll, where they could be serviced in uncontaminated water. The move was completed by the end of September.

A major task at Kwajalein was to offload ammunition stored aboard some target ships before it became dangerously unstable, even though the ships were still contaminated. The work, which had to be carried out under strict radiation safety conditions, continued into the fall of 1946.

Eight of the major target ships and two submarines were eventually towed back to the United States and Hawaii for radiological inspection. Thirteen target ships that were only slightly contaminated were remanned and sailed back to the United States. The remaining target ships were sunk off Bikini Atoll, off Kwajalein Atoll, or near the Hawaiian Islands between 1946 and 1948. The support ships were decontaminated as necessary at Navy shipyards in the United States and rejoined the fleet after receiving operational clearance.

Scientists conducted a formal biological survey of Bikini Atoll in the summer of 1947 to study long-term effects of the CROSSROADS tests. They concluded that the nuclear detonations had caused only minor, transient disturbance to the plant and animal populations, most of which appeared to be growing normally. Also in 1947, Navy divers visited the ships that were sunk by the blast, where they documented their damage and retrieved instruments.

## **Radiation Safety**

When JTF began planning the radiation safety program for CROSSROADS, they had little experience in organizing such programs, only a few experienced radiation safety (rad-safe) officers, and inadequate equipment. A concentrated effort, however, in the spring of 1946 by veterans of the Manhattan Project and military officers created an organization that performed remarkably well during CROSSROADS. JTF personnel established rad-safe policies and procedures and a rad-safe organization, recruited military medical officers and others to train as rad-safe monitors, and rounded up enough radiac instruments to service ABLE (more equipment arrived just in time for BAKER).

The new rad-safe policies emphasized detection and avoidance. Procedures were developed to identify and label radiation areas and then to restrict who entered the areas and how long they stayed. JTF personnel also began developing decontamination techniques, although they were not prepared for the massive decontamination necessary after BAKER. And they established a system of personal dosimetry using film badges.

About 15 percent of JTF personnel were issued at least one of the approximately 19,000 film-badge dosimeters during CROSSROADS. Approximately 6,600 personnel were on islands or ships that had no potential for radiation exposure. Those personnel expected to be at greatest radiological risk were badged, as were a percentage of each group working in less contaminated areas. Individuals were removed for one or more days from areas and activities of possible exposure if their badges showed more than 0.1 rem\* per day of exposure.

## **Radiation Protection Standards**

Safety standards were established to limit the exposure of participants to the effects of nuclear detonations while, at the same time, allowing them to accrue small doses of radiation performing their missions in contaminated areas.

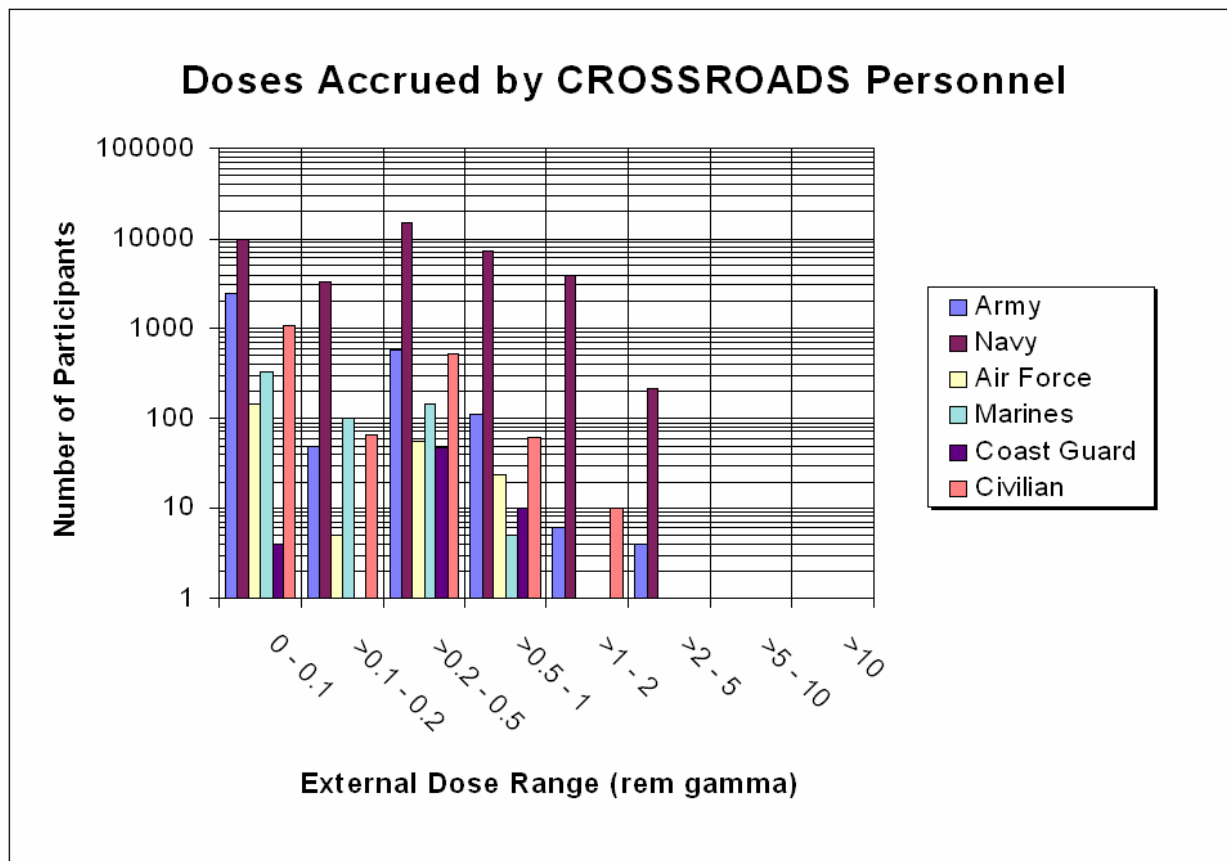
All CROSSROADS operations were performed under radiological supervision intended to prevent personnel from being exposed to more than 0.1 rem per day (equivalent to the standard in 1946 for radiation workers in the United States). At the time, this was considered to be an amount of radiation that could be tolerated for long periods without any harmful effects on health. Apparently referring to an emergency situation, the Operation Plan also stipulated that an individual was not to have a total dose of over 50 or 60 rem in two weeks (more than one year's dose permitted otherwise).

## **Radiation Doses**

Apart from the crew of a patrolling destroyer, USS O'BRIEN (DD 725), which encountered a slightly contaminated rain shower after BAKER, no personnel were exposed to fallout, which was blown by prevailing winds to the north, away from task force ships. The greatest potential for exposure to ionizing radiation was from the residual gamma radiation in the lagoon water and on the target ships contaminated by direct neutron activation or indirectly from radioactive contaminants in water. There also was potential for exposure to alpha radiation from unfissioned nuclear debris.

Personnel doses have been reconstructed under the NTPR Program for the unbadged crewmembers of the ships. The analysis evaluated and combined the several sources of radiation during CROSSROADS that an individual might have been exposed to, such as the contaminated lagoon water, low-level intensities on support ships, and radiation onboard contaminated target ships. The calculations relied upon radiation data recorded by radiation safety personnel in 1946, which have been entered into a computer model that includes such factors as the radiation-shielding properties of ships' hulls and realistic patterns of daily personnel activity on weather decks and below. The actual movements of each ship were then used to reconstruct a generic dose for the crew. Calculated generic doses range from 0 to 2 rem (gamma) for support ships. Doses for target crews that reboarded and remained on target ships after BAKER were on average higher than those for support ship crews. Uncertainty analysis provides the level of confidence in the calculated doses.

The highest doses accumulated during CROSSROADS were about 3 rem. Three-quarters of the participants had total doses of less than 0.5 rem. The totals of reconstructed and film badge doses for CROSSROADS participants are depicted below.



*\* A rem is a radiation protection unit of measure that quantifies the risk of biological effects resulting from exposure to ionizing radiation. Ionizing radiation is any radiation (gamma, x-ray, beta, neutron or alpha) capable of displacing electrons from atoms or molecules, thereby producing ions. According to the National Council on Radiation Protection and Measurements (NCRP, Report No. 93, Table 8.1), the general U.S. population receives about 0.36 rem per year from natural background radiation sources (radon, cosmic rays and rocks) and man-made radiation sources (medical diagnostic x-rays and consumer products).*

For more information on reconstructed doses, see the three-volume report "Analysis of Radiation Exposure of Naval Units of Operation CROSSROADS" (DNA-TR-82-05), available online at [http://www.dtra.mil/rd/programs/nuclear\\_personnel/pubs.cfm](http://www.dtra.mil/rd/programs/nuclear_personnel/pubs.cfm). Also see the report "Operation CROSSROADS 1946" (DNA 6032F), available online at [http://www.dtra.mil/rd/programs/nuclear\\_personnel/atr.cfm](http://www.dtra.mil/rd/programs/nuclear_personnel/atr.cfm).

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